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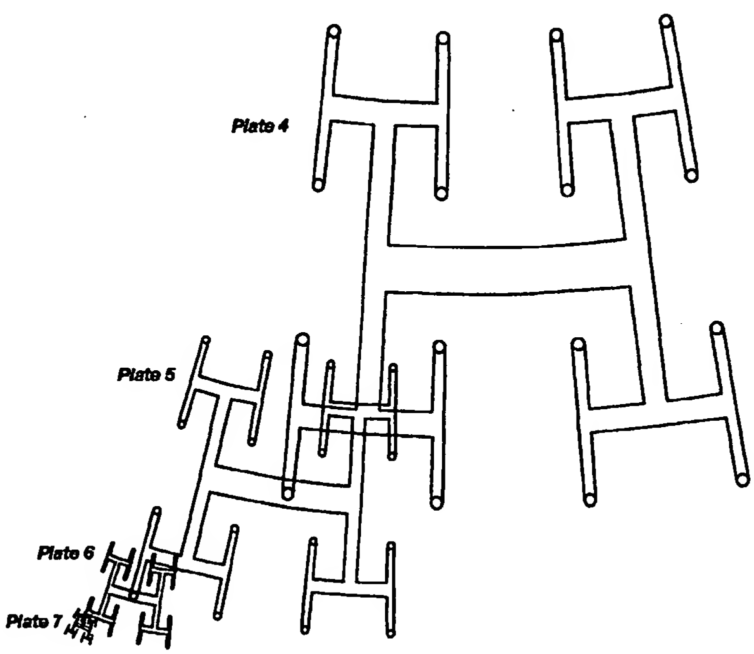

(57) Abstract

Fluid transporting fractal devices, which can be employed whenever a controlled distribution and/or collection of fluids is desired, are constructed to position fractal stages of either progressively smaller or progressively larger scales along the direction of flow (Plates #1–8). A preferred construction assigns generations of recursive fractal pattern to plates arranged in a stack.

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FRACTAL STACK FOR SCALING AND DISTRIBUTION OF FLUIDS

This application claims the benefit of U.S. Provisional Application No. 60/079,028 filed 23 March 1998.

TECHNICAL FIELD

This invention pertains to the scaling and distribution of fluids. It provides fractal structures arranged to minimize the intersection of recursive fluid flow paths.

BACKGROUND ART

Fluid transporting fractal structures ("fractals") have recently become available for the control of fluid flow. U.S. Patent No. 5,354,460, the disclosure of which is incorporated by reference herein, describes a fractal structure embodied as a fluid distributor/collector. A notable characteristic of the device disclosed by the '460 patent is its recursive scaling configuration which is, for purposes of this disclosure, regarded as a "fractal." This fractal configuration provides exceptionally even fluid flow distribution.

PCT/US97/17516, the disclosure of which is incorporated by reference herein, describes the use of space filling fluid transporting fractals for use as alternatives to the scaling and distribution function of turbulence.

"Fractal scaling," as contemplated by this invention, is a recursive process by which an algorithm is applied in successive stages, each time to process the outputs from an immediately preceding stage. A simple case for purposes of illustration is to apply the algorithm "divide a flow stream into two equal flow streams." According to this example, a flowing stream is divided into two equal streams of half the initial volume during a first stage. Each of the two resulting streams is then similarly divided to produce a total of four equal streams of reduced volume in a second stage. Those four resulting streams are then divided into eight equal streams of reduced volume in a third stage, and so on, through as many stages as are desired to achieve the distribution of fluid flow required for a particular application.

Mathematical models of fractal geometry assume that each division at each stage is identical and that precisely identical geometry is followed through each branch of successive stages. In practice, it is recognized that absolute adherence to a mathematical model is impractical. Accordingly, fractal devices are usually constructed

to approximate a theoretical model. That is, because of manufacturing and space constraints, commercial fractals often make use of "similar," rather than "identical" fractal patterns. This disclosure should be understood within that context. The practical consequences of this departure from theoretical are generally minimal within the practical realm.

DISCLOSURE OF INVENTION

The present invention comprises an improved fluid transporting fractal. Devices constructed in accordance with this invention can be employed whenever a controlled distribution and/or collection of fluids is desired. A notable feature of the structures of this invention is the positioning of fractal stages along the direction of flow. That is, stages of either progressively smaller or progressively larger scales are arranged serially in the direction of flow. It is within contemplation to construct an entire device, or multi-stage segment of such a device, as a unitary structure, e.g., through investment, shell or lost wax casting techniques. The multi level fractals of this invention are more conveniently provided, however through the use of a stack of fractal elements in an assembly, or "fractal stack." To avoid redundancy of description, this disclosure gives primary emphasis to fractal stacks utilized as distributors.

The individual elements of a typical fractal stack are three-dimensional components, structured and arranged for juxtaposed assembly in a specified sequence. Each fractal element is provided with channels and ports constituting a portion of a fractal fluid scaling array. Various portions of the scaling array may be assigned to individual elements, those portions being selected such that a practical recursive fractal array results from the assembly of the elements, in proper sequence, into the fractal stack. A presently preferred arrangement assigns the fluid flow channels of a specified fractal stage to a single specified fractal element. It is within contemplation to assign channels of different fractal stages to a single fractal element, and it is also within contemplation to divide channels of a specified fractal stage among a plurality of fractal elements. The channels associated with a particular element may be positioned on a single side or on the opposed sides. In the latter case, the channels of a fractal stage may be defined by juxtaposed matching grooves at the interfaces between adjacent elements.

An exemplary fractal element has a relatively large cross section normal the direction of fluid flow, to accommodate the largest fractal pattern in the stack. This pattern is typically that of the final fractal stage, and its "footprint" is dependant upon (among other things) the fractal number (the number of stages) accommodated by the stack. A relatively small height dimension is required to accommodate the flow channels arranged in a fractal pattern within, (most often openly communicating with either or both interfacing surfaces of the element). Such elements take the form of short prisms, usually cylindrical, and are designated "fractal plates," for purposes of this disclosure. Fractal plates may be stacked upon one another such that fractal distribution to progressively smaller scales occurs as fluid passes through the stack. The device therefore acts as a fluid distributor. The structures of this invention may alternatively be utilized as a fluid collector. For such applications, fluid is caused to pass from the smallest to the largest fractal scale. Near limitless scaling of fluid motion can be accomplished with this invention by the addition of fractal plates to the stack, that is, by increasing the fractal number of the stack.

According to certain embodiments of this invention, a "finishing" structure, such as a plate or plates, may be added to the fractal stack to provide additional fluid scaling. This final scaling stage is beneficial when the fractal manufacturing techniques used on the larger scale plates reaches a practical limit. The finishing plate allows a final fluid scaling to be implemented at the smallest of scales. The finishing plate can be of any material or configuration which provides a scaling effect. For example, fins, corrugations, column packings, screens, sponges or other structures capable of providing a tortuous, (or mixing-type), path for the fluid exiting the final fractal pattern can be used for this purpose. Fluid collision or impinging structure can also be used for the finishing plate. For example, small obstructions may be positioned in the path of the final fluid exits. Fluid splashing against these structures is broken into streams or droplets of smaller scales, thereby undergoing a final scaling effect.

The invention is thus applied in practice to a fractal fluid flow system in which recursive flow paths are arranged in a fractal pattern including generations of progressively increasing or decreasing scale. The improvement of the invention generally comprises providing portions of the fractal pattern in stacked arrangement with respect to each other, whereby to avoid intersection of recursive flow channels.

The generations of progressively increasing or decreasing scale are typically positioned between an inlet and an outlet, whereby to modify the scale of fluid flow through the system. The present invention arranges successively such generations of structural flow channels at different distances from the inlet in the direction of the outlet.

Most often, portions of the fractal pattern are provided on structural elements assembled in stacked arrangement with respect to each other. The structural elements are typically approximately congruent geometric solids with flow channels arr The invention is thus applied in practice to a fractal fluid flow system in which recursive flow paths are arranged in a fractal pattern including generations of progressively increasing or decreasing scale. The improvement of the invention generally comprises providing portions of the fractal pattern in stacked arrangement with respect to each other, whereby to avoid intersection of recursive flow channels. The generations of progressively increasing or decreasing scale are typically positioned between an inlet and an outlet, whereby to modify the scale of fluid flow through the system. The present invention arranges successively such generations of structural flow channels at different distances from the inlet in the direction of the outlet.
anged in conformance to the fractal pattern so as to constitute fractal elements. Ideally, these fractal elements comprise plates, which contain fractal patterns, stacked, one upon another, to provide a fractal stack constituting means for the distribution of fluid to progressively different scales as fluid is caused to pass through the stack from its inlet to its outlet. The inlet may be located to direct fluid to either the largest or smallest scale fractal generation.

Particularly when the stack is operated as a distributor, it may include finishing structure at one (outlet) end, structured and arranged to promote even distribution of fluid normal the direction of fluid low through the stack. The finishing structure is preferably constructed and arranged to provide multiple channel tortuous pathways for fluid exiting the fractal pattern. The opposite (inlet) end of the stack may comprise a structural element containing distribution channels arranged to receive fluid from a primary inlet and to distribute scaled quantities of that fluid to respective inlets of a first generation of the fractal pattern.

Another embodiment of this invention provides open area around the fractal pattern of the plates so that fluids can flow through the bulk of the device in either

direction without interfering with the scaling of the fluid inside the fractal. This arrangement is useful for applications such as counter-current operation or when a fluid is to be introduced or taken from a stream of fluid passing through the stack.

Because fractals are, by definition, invariant to scaling, this invention can be used for any size application and still provide any desired range of fluid scaling. This device theoretically enables infinite scaling of fluids. The existing limits on manufacturing objects of very large or very small size impose practical limits upon sizing at present. It is understood, however, that as manufacturing methods for constructing large or small objects improve, those methods can be applied to expand the practical range of scaling offered by this invention.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is a view in side elevation, illustrating a fractal stack comprising eight plates;

FIG. 2 is a top plan view of Plate 1 of FIG. 1;

FIG. 3 is a top plan view of Plate 2 of FIG. 1;

FIG. 4 is a top plan view of Plate 3 of FIG. 1;

FIG. 5 is a top plan view of Plate 4 of FIG. 1;

FIG. 6 is a diagram illustrating the fractal pattern effected by plates 4, 5, 6 and 7 of FIG. 1;

FIG 7 is a pictorial view of Plate 8 of FIG. 1; and

FIG. 8 is an enlarged pictorial view of a portion of FIG. 7.

BEST MODES FOR CARRYING OUT THE INVENTION

The fractal stack illustrated by FIG. 1 includes eight plates, although the invention contemplates embodiments having either fewer or more plates, depending upon the requirements of a particular application. As illustrated, circular ports pass through the plates, and elongate channels between inlet and outlet ports comprise grooves cut, molded or otherwise formed in one surface of the plate. Plates 1-3 provide a general preliminary scaling of the fluid introduced to the inlet 21 (FIG. 2) and divided through channels 23 to ports 25 (FIG. 3) and then through channels 27 to ports 29 (FIG. 4). Plate 3 provide a 6-way conduit scaling of the fluid introduced to the inlet 21. Plate 3. provides a 36-way conduit scaling of the fluid. Plates 4, 5, 6, and 7 are fractal elements,

which allow the near limitless scaling of this invention. (See FIGS. 5 and 6.) Any number of fractal plates can be used, depending upon the fine scaling requirements of the application at hand. Only four such plates are illustrated. Plate 8 represents an optional "finishing" plate.

Plate 4 (FIG. 5) is the first fractal scaling plate in the illustrated system. In designing a system, conduit plates (1, 2 and 3) preceding the fractal plates (4, 5, 6, and 7) can be modified with respect to number and pattern as required to coordinate liquid feed to the subsequent fractal plates. For example, FIG. 5 shows 3 rings of fractal pattern. Because of space limitations, the fractal pattern of the innermost ring differs somewhat from that of the outer two rings. Adding additional rings, e.g., for larger diameter devices, will require a larger number of conduit branches on the previous non-fractal scaling plate or plates. It can also be seen from FIG. 5 that additional fractal scaling pattern may be provided on any fractal plate before passing the fluid to the next plate in the series. It is not usually necessary to pass fluid to the next plate until a crossover of the fractal conduit pattern is imminent.

FIG. 6 illustrates the basic fractal flow distribution pattern provided through plates 4, 5, 6 and 7. Scaling of the fluid can continue without limit (within manufacturing constraints) by adding additional fractal plates to the stack (FIG. 1). FIG. 6 shows that individual fluid conduits would inevitably overlap were the entire pattern of fluid conduits placed on a single plate.

FIG. 7, while illustrating a finishing plate, also illustrates pictorially the general shape and relative dimensions of all of the plates in the stack. Bolt holes 35 are provided in each of the plates for connecting them in position within the fractal stack. A structural element 37 is positioned atop a fluid exit port 39. As best shown by the enlarged depiction of FIG. 8, the element 37 is constructed of bars 41, arranged to provide a final tortuous pathway, which finishes spreading of the fluid evenly over the cross section of the stack.

INDUSTRIAL APPLICABILITY

Devices constructed in accordance with this invention can be employed whenever a controlled distribution and/or collection of fluids is desired.

Any fluid process may benefit from this invention if control of fluid scaling is advantageous. Without limiting the scope of the appended claims in any way, exemplary applications of the invention include: general scaling of fluids from large to smaller scale motion; general scaling of fluids from small to larger scale motion; rapid formation of fluid surfaces; rapid formation of low-turbulence fluid surfaces; rapid collection of fluid surfaces. Apparatus constructed in accordance with this invention may, among other things, be applied to the introduction of low turbulence fluid surfaces into other fluids; adsorption or absorption processes; chromatography procedures; ion exchange operations; gas/liquid counter-current applications; distillation equipment; reactors; aerators and flow through mixers. While the foregoing examples are expressed in terms of "motion" and "surfaces," they may also be conceptualized in terms of fluid volumes or streams.

CLAIMS

What is claimed is:

1. In a fractal fluid flow system in which recursive flow paths are arranged in a fractal pattern including generations of progressively increasing or decreasing scale, the improvement comprising providing portions of said fractal pattern in stacked arrangement with respect to each other, whereby to avoid intersection of recursive flow channels.

2. An improvement according to Claim 1, wherein said portions of said fractal pattern are provided on structural elements assembled in stacked arrangement with respect to each other.

3. An improvement according to Claim 2, wherein said structural elements are approximately congruent geometric solids with flow channels arranged in conformance to said fractal pattern.

4. An improvement according to Claim 3, wherein said structural elements comprise plates, which contain fractal patterns, stacked, one upon another, to provide a fractal stack constituting means for the distribution of fluid to progressively different scales as fluid is caused to pass through the stack.

5. An improvement according to Claim 4, further including finishing structure at an output end of a said stack operated to function as a distributor, whereby to promote even distribution of said fluid normal the direction of flow of said fluid.

6. An improvement according to Claim 3, wherein said structural elements comprise fractal elements arranged in a fractal stack with an inlet at a first end of said stack and an outlet at a second end of said stack.

7. An improvement according to Claim 6, wherein said first end of said stack comprises a structural element containing distribution channels arranged to receive fluid

from said inlet and to distribute scaled quantities of said fluid to respective inlets to a first generation of said fractal pattern.

8. An improvement according to Claim 6, further including finishing structure at said output end of a said stack operated to function as a distributor, whereby to promote even distribution of said fluid normal the direction of flow of said fluid.

9. An improvement according to Claim 8, wherein said finishing structure is constructed and arranged to provide multiple channel tortuous pathways for fluid exiting said fractal pattern.

10. In a fractal fluid flow system in which recursive structural flow channels are arranged in a fractal pattern including generations of progressively increasing or decreasing scale between an inlet and an outlet, whereby to modify the scale of fluid flow through the system, the improvement comprising arranging successive said generations of structural flow channels at different distances from said inlet in the direction of said outlet, whereby to avoid intersection of recursive flow channels.

11. An improvement according to Claim 10, wherein said fractal pattern is distributed among structural fractal elements arranged in stacked relationship.

12. An improvement according to Claim 11, wherein said fractal elements are arranged in a fractal stack with an inlet at a first end of said stack and an outlet at a second end of said stack.

13. An improvement according to Claim 12, wherein said first end of said stack comprises a structural element containing distribution channels arranged to receive fluid from said inlet and to distribute scaled quantities of said fluid to respective inlets to a first generation of said fractal pattern.

14. An improvement according to Claim 12, further including finishing structure at said output end of a said stack operated to function as a distributor, whereby

to promote even distribution of said fluid normal the direction of flow of said fluid.

15. An improvement according to Claim 14, wherein said finishing structure is constructed and arranged to provide multiple channel tortuous pathways for fluid exiting said fractal pattern.

16. An improvement according to Claim 15, wherein said first end of said stack comprises a structural element containing distribution channels arranged to receive fluid from said inlet and to distribute scaled quantities of said fluid to respective inlets to a first generation of said fractal pattern.

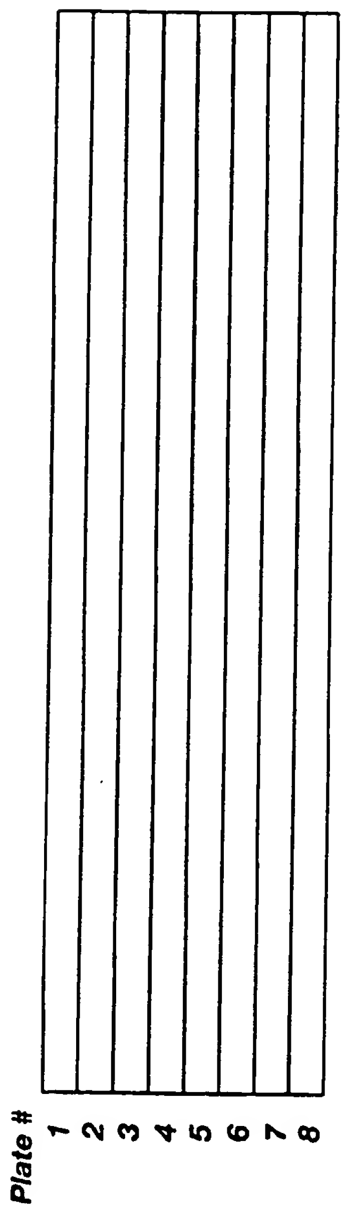

Fig. 1

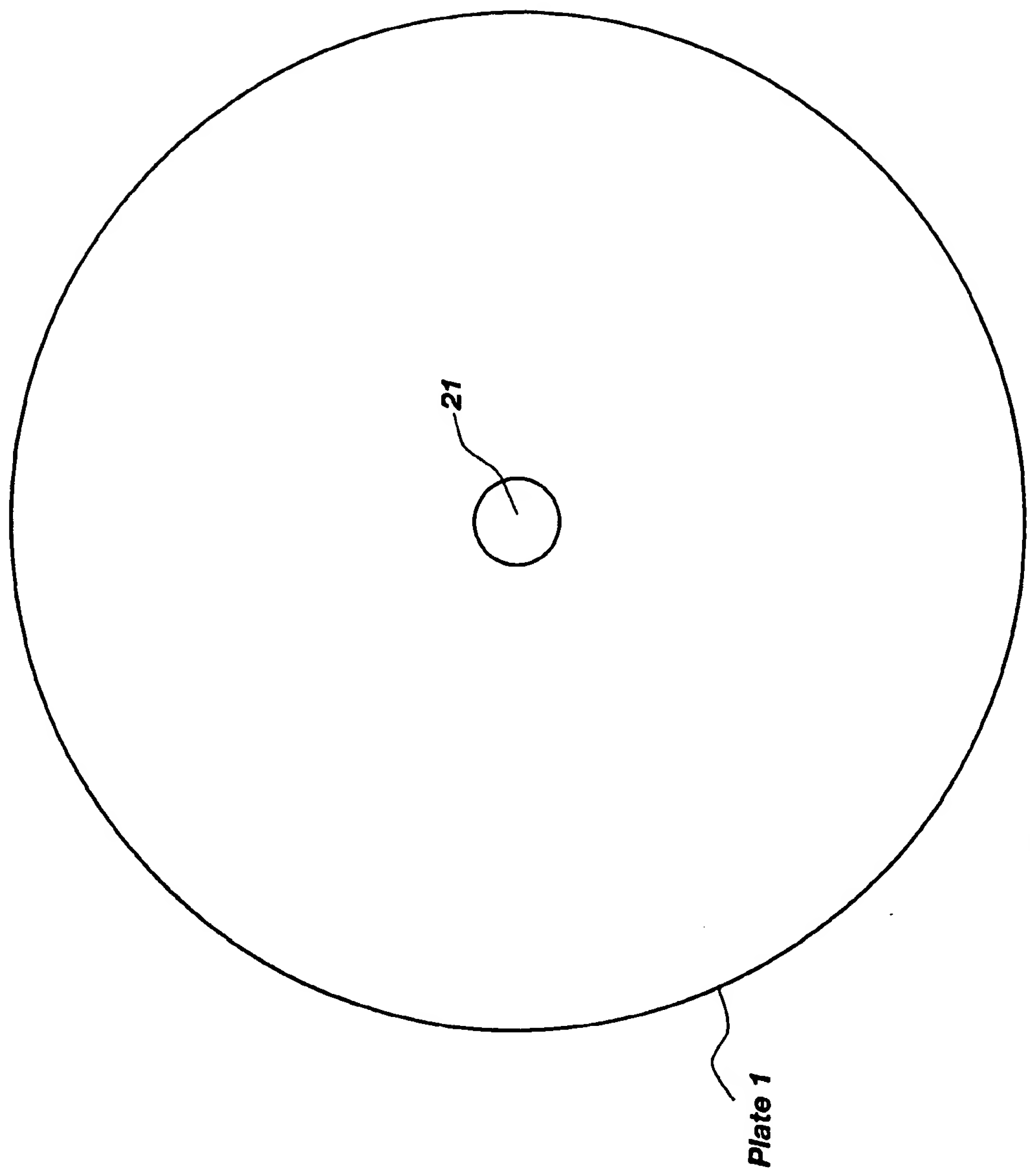

Fig. 2

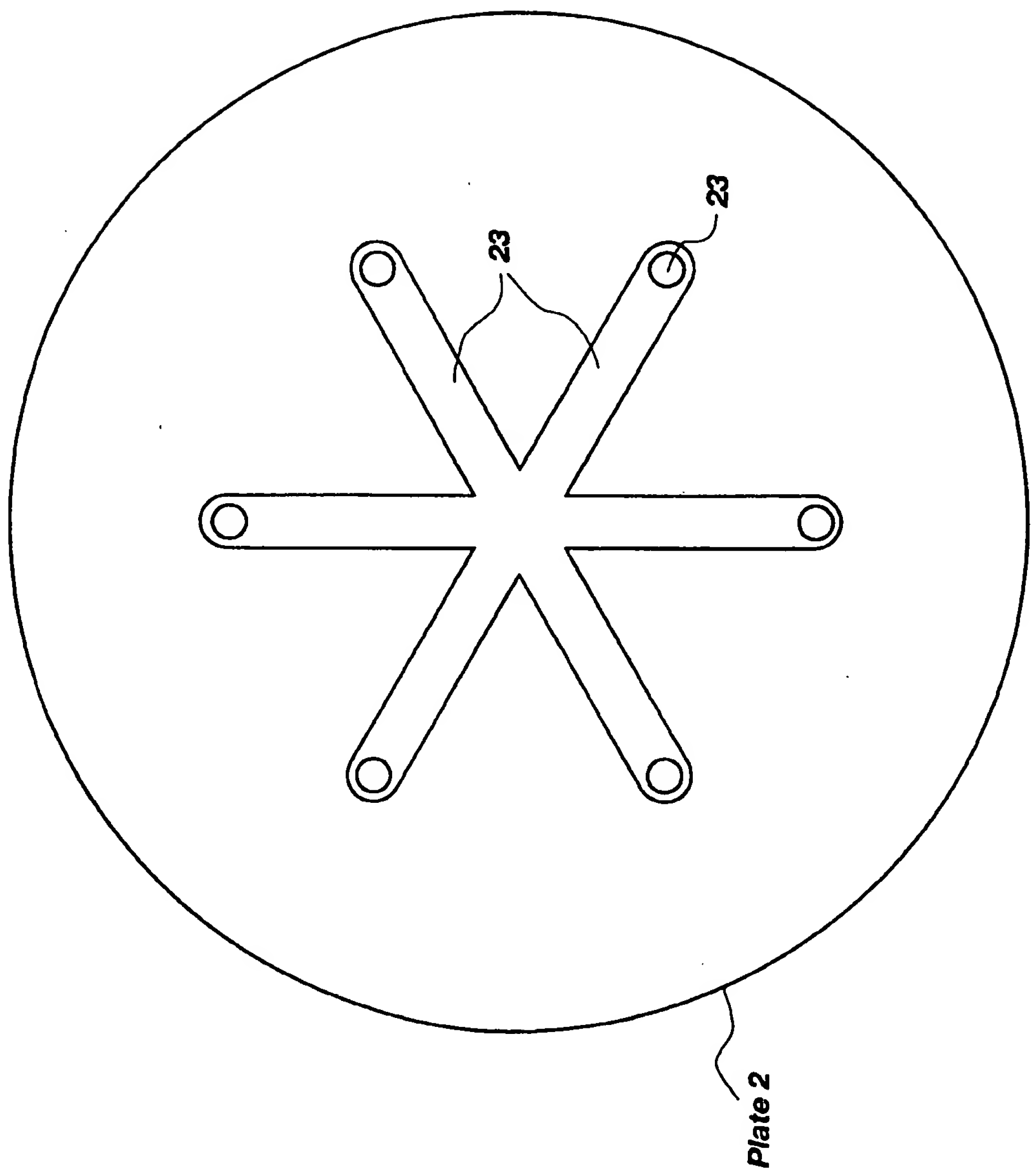

Fig. 3

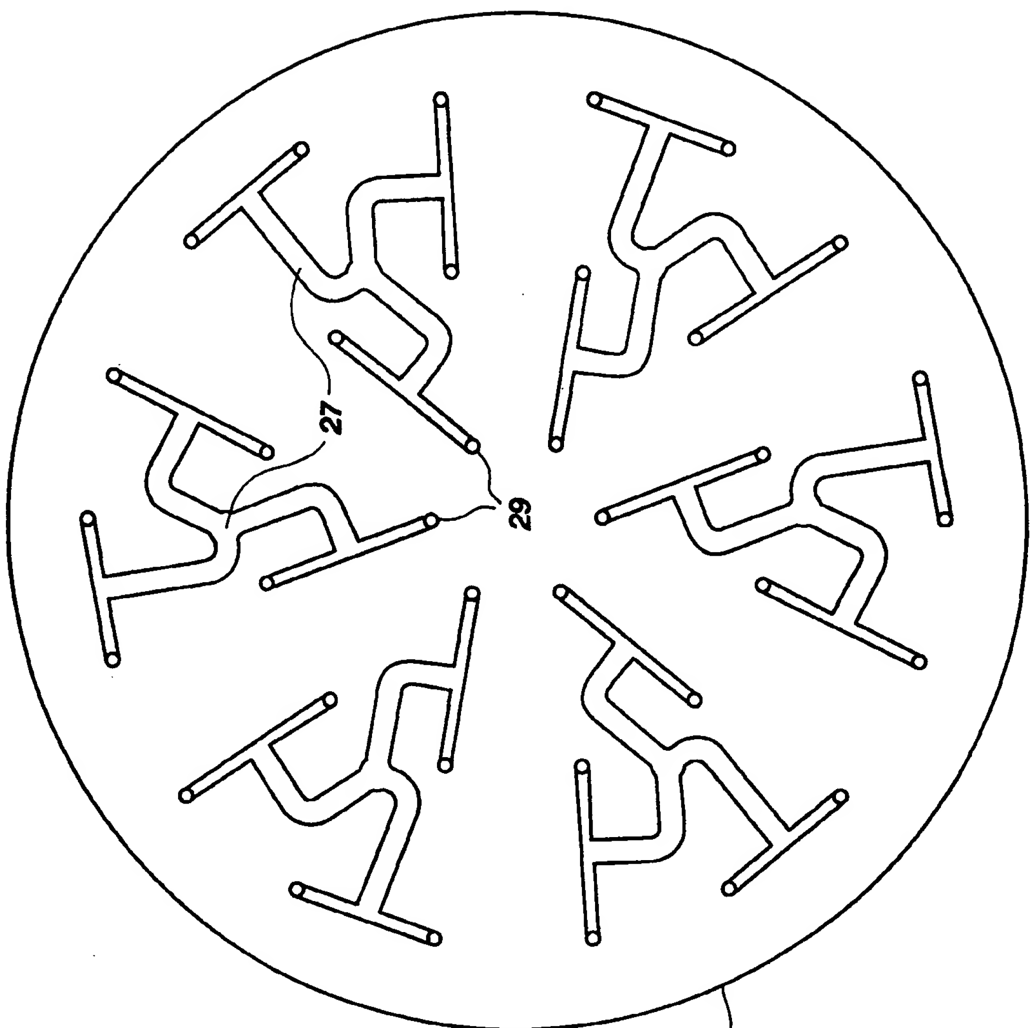

Fig. 4

Plate 3

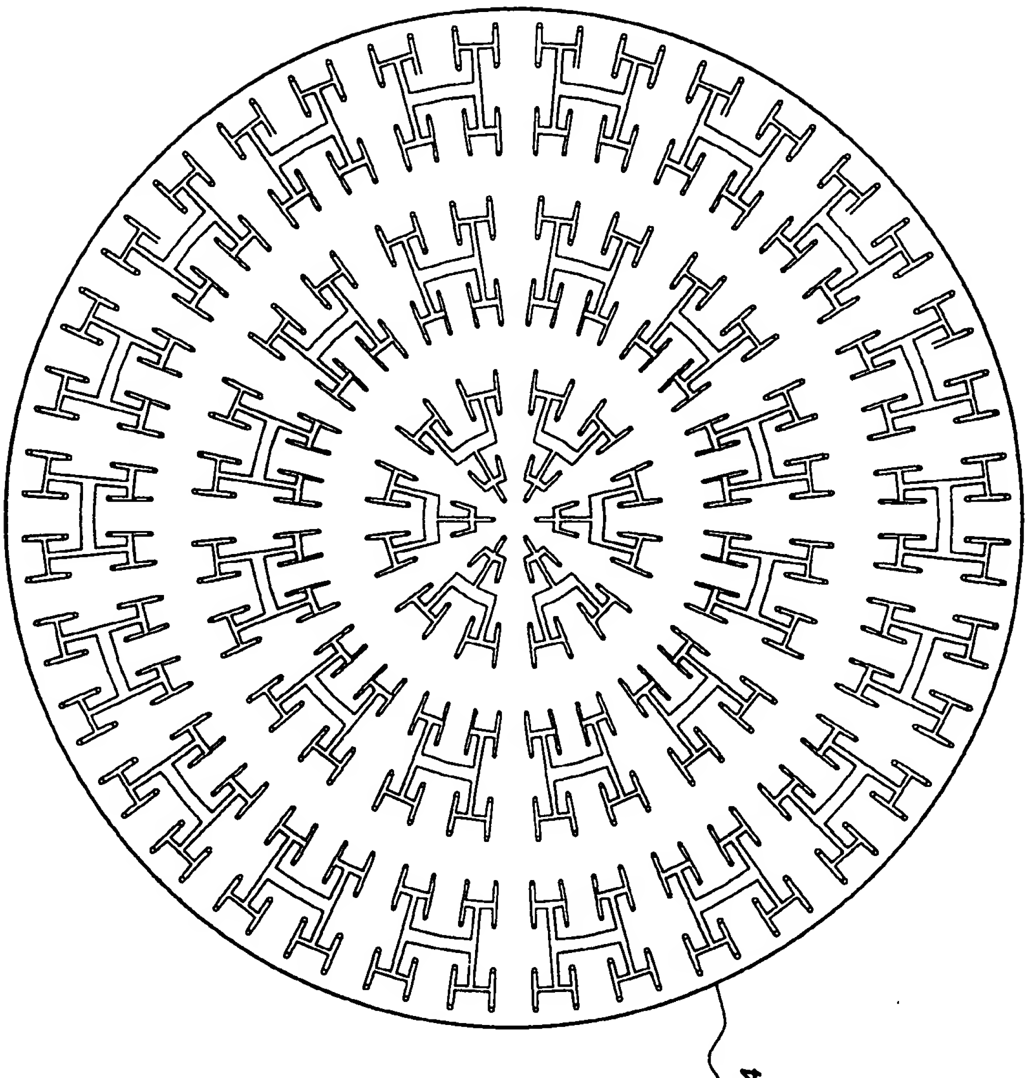

Fig. 5

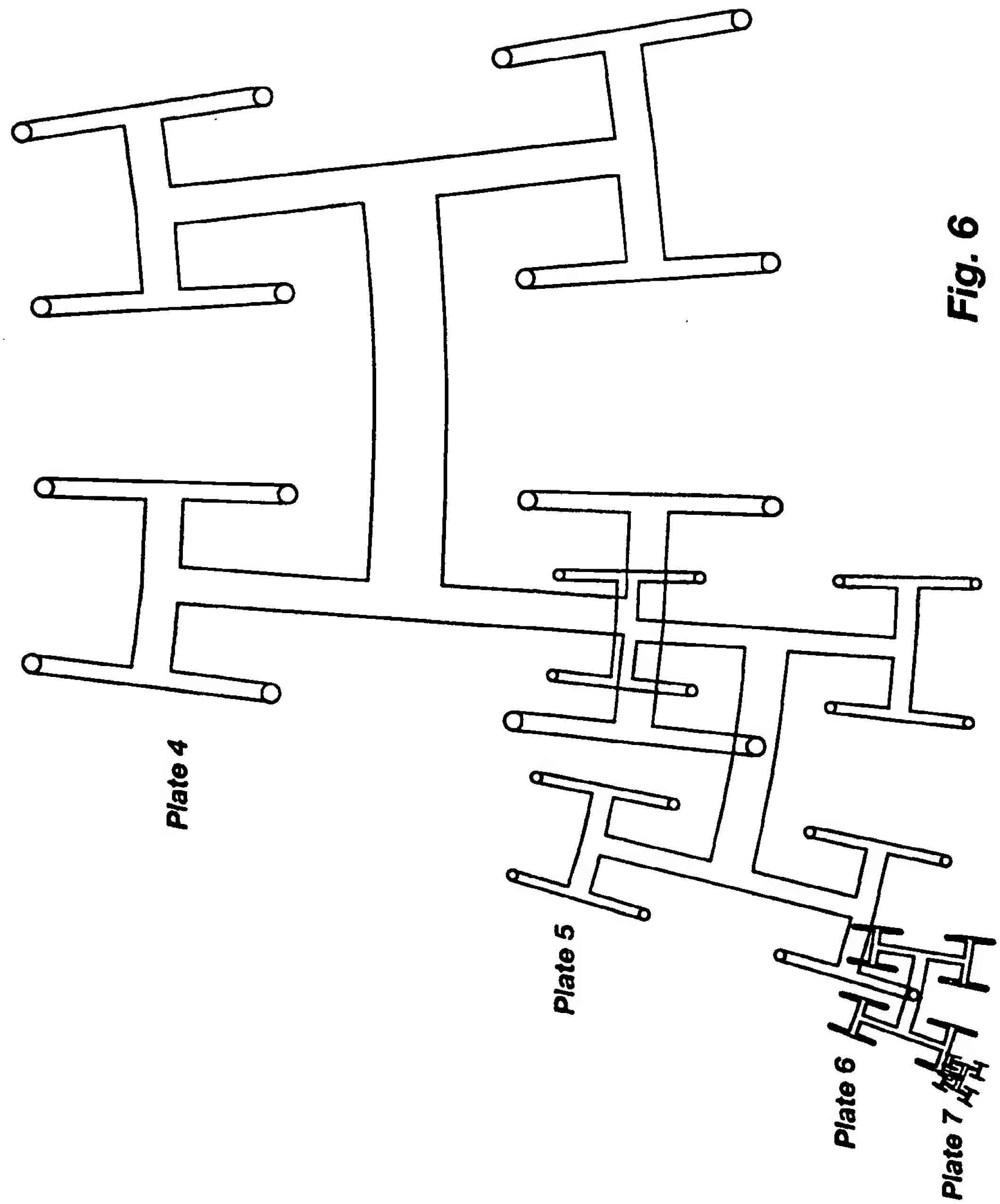

Fig. 6

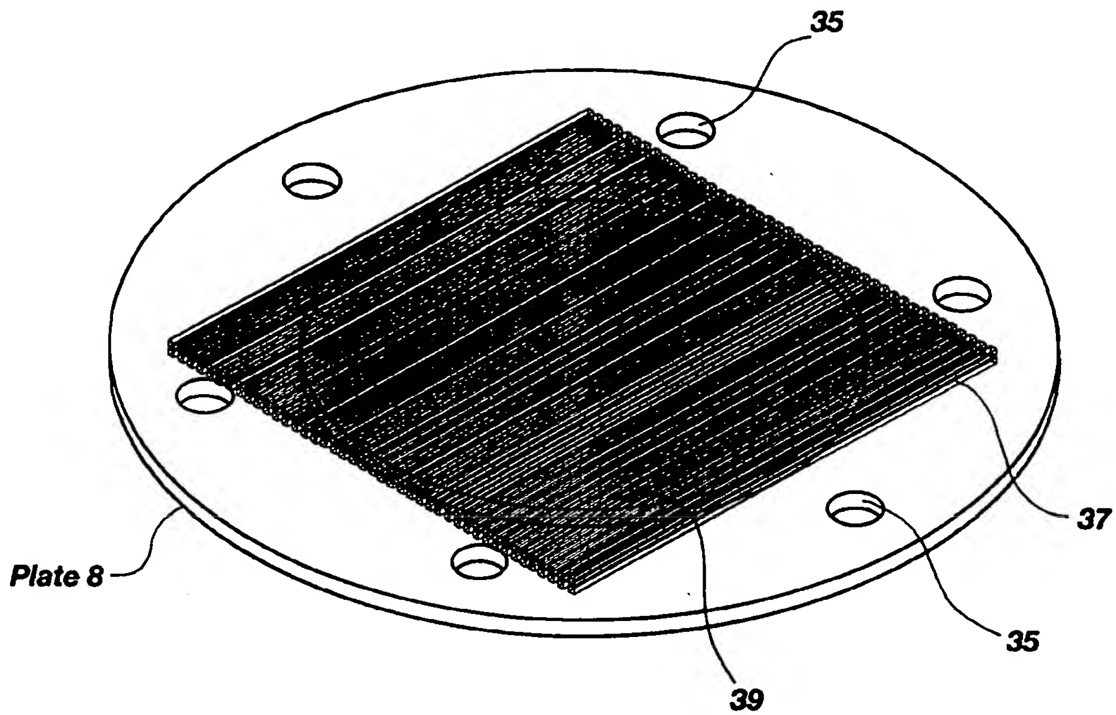

Fig. 7

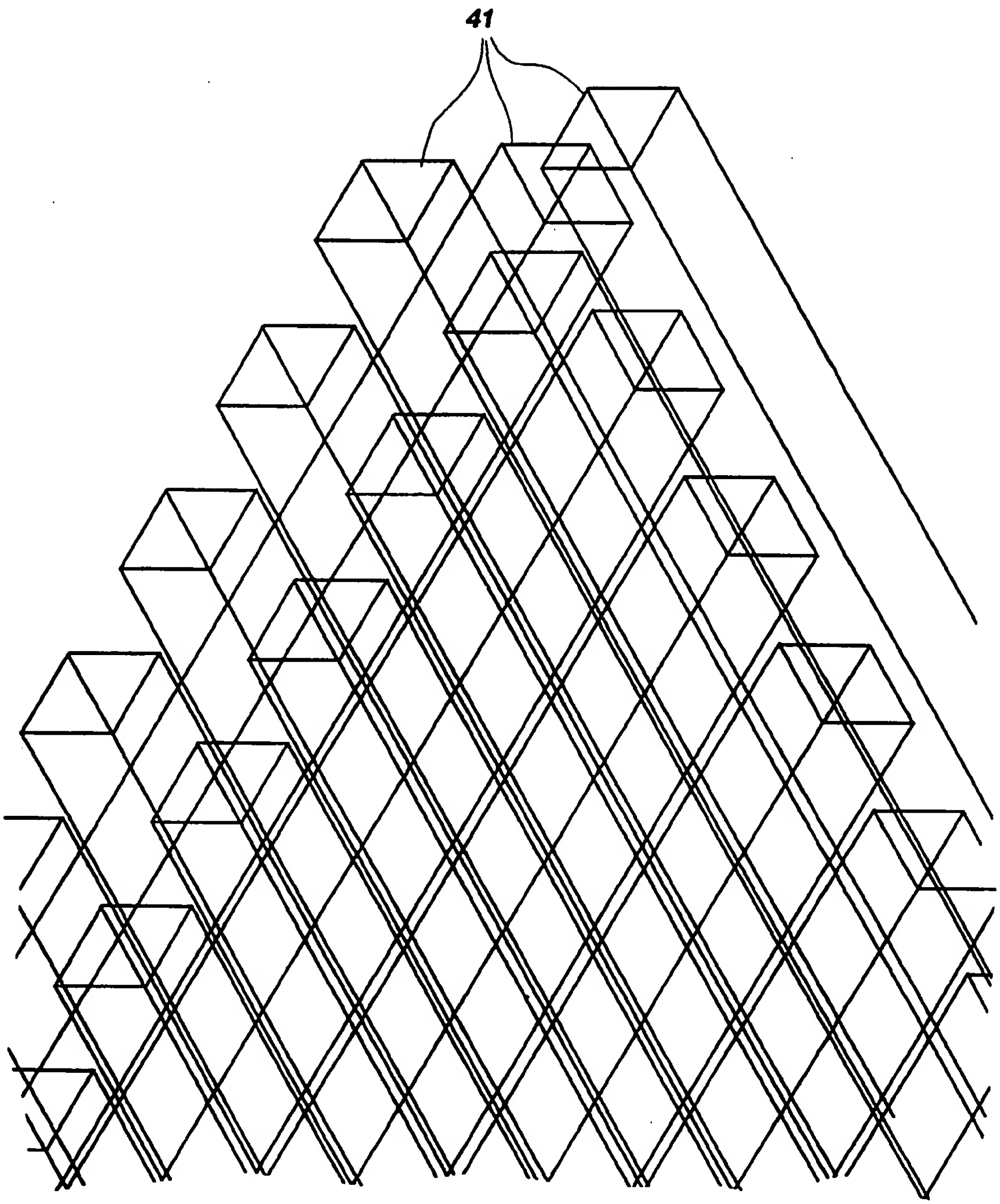

Fig. 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/06245

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :BOIF 5/06
US CL :366/336, 341
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 366/336, 337, 338, 339, 340, 341, 342, 349, 174.1, 183.1; 137/625.28, 599; 165/109.1, 159, 172, 296, 100, 102; 216/002

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WEST (Derwent), search terms: fractal, channel, fluid

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,304,487 A (WILDING et al) 19 April 1994, see entire document, figure 1.	1
A,P	WO 98/14268 A (AMALGAMATED RESEARCH INC.) 09 April 1998. See entire document	1-16

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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